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The effect of cigarette smoke from the mother on bronchial responsiveness and severity of symptoms in children with asthma

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The effect of parental smoking was assessed in 94 consecutively observed children, aged 7 to 17 years, who had a history of asthmatic wheezing. The 24 children whose mothers smoked, when they were compared with children whose mothers did not smoke, had 47% more symptoms, a 13% lower mean FEV$_1$ percent, a 23% lower mean FEF$_{25-75\%}$, and fourfold greater responsiveness to aerosolized histamine. A dose response was evident. There was a highly significant correlation between the results of the tests and the number of cigarettes the mother smoked while she was in the house. The differences between the children of smoking and nonsmoking mothers were greater in older than in younger subjects. The smoking habits of the father were not correlated with the severity of the child's asthma. (J ALLERGY CLIN IMMUNOL 77:575-81, 1986.)

Although cigarette smoke from parents is believed to increase wheezing among their children,[1] results from different surveys have been conflicting. In some studies parental smoking has no apparent effect[2, 3]; in other studies greater frequency of wheezing is observed only if the mother smokes[4]; in yet other studies the prevalence of wheezing increases with the number of parents that smoke.[5] Similarly, spirometric values

Abbreviations used
FEF$_{25-75\%}$: Maximal midexpiratory flow rate between 25% and 75% of FVC
PC$_{20}$: Provocation concentration of histamine causing a 20% fall in FEV$_1$

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TABLE I. Comparability of groups

Features	Mother Nonsmoker	Mother Smoker	p Value (two-tailed)
	n = 70	n = 24	
Mean age (yr)	11.1	10.8	0.77
M:F ratio	21:14	19:5	0.15
Previous surgical operation*	27 (42%)	8 (38%)	0.94
More than three colds per year†	22 (49%)	9 (56%)	0.87
Gas stove in the kitchen‡	6 (12%)	2 (8%)	0.94
Dog or cat present	26 (49%)	11 (58%)	0.69
Any skin test positive	55 (79%)	21 (87%)	0.51
Mean diameter wheal to *D. farinae* (mm)	2.3 ± 0.4	1.6 ± 0.6	0.85

*Nine subjects were omitted from the analysis because of missing data.
†Thirty-three subjects were omitted from the analysis because of missing data.
‡Twenty subjects were omitted from the analysis because of missing data.

are variously reported as unaffected[2, 6] or as slightly decreased, although significantly,[5, 7-9] when parents smoke.

These epidemiologic surveys have all been carried out on large representative groups of children. Because of this method of selection, those most likely to be affected by the smoke, the ones with asthma, were in the minority. In order to assess the effect of passive smoking on these more susceptible subjects, we examined a group of children who had a history of asthma or wheezing. Histamine bronchial challenge was performed in addition to spirometry because adults who themselves smoke may have increased bronchial responsiveness.[10, 11] Consequently, we suspected that children who are passive smokers might also have more irritable bronchi, resulting in an exacerbation of their wheezing.

METHODS

The study population consisted of 94 children, aged 7 to 17 years, who were referred consecutively to one of the authors for evaluation of suspected allergic disease and who had a history of wheezing or asthma. A trained interviewer asked the following standardized questions of the accompanying parents about the child's illness during the past 12 months: the frequency of wheezing, the frequency with which bronchodilator medications had been administered, whether or not corticosteroid tablets or corticosteroid aerosols had been used, and whether the child wheezed on exertion. Each feature in the history was assigned a range of scores; the scores for each individual were added to produce a summary rating called an asthma history score.[12] Children with no symptoms or medication for asthma during the previous year, for example, had a score of 0, and children with the most severe asthma had a summary score of 14 (Appendix). Inquiry was also made about other factors. The interviewer asked whether there was a gas cooking stove in the home, a device whose fumes might be irritating to the bronchi; whether there was a dog or a cat in the house, animals whose emanations might cause sensitization; whether the child had had a surgical operation, since the frequency of such a procedure might indicate the readiness with which the parents sought and followed medical advice; the number of colds in the past year, since respiratory infections themselves may precipitate and worsen asthmatic attacks; and, finally, the parents were asked how many cigarettes, cigars, and pipefuls of tobacco they smoked, both inside and outside the house. The child was asked privately whether or not he or she smoked.

Forced expiratory spirogram

Forced expiratory maneuvers were performed until there were three in which the FVC agreed within 5%. This was always achieved within five efforts. The tracing that had the greatest sum of FVC and FEV_1 was used for all measurements.[13] The FVC, FEV_1, and FEF_{25-75} were expressed as a percentage of predicted mean for age, sex, and height.[14]

The spirogram was recorded with a Pulmonor (Jones Medical Instrument Co., Oak Brook, Ill.) waterless spirometer that was calibrated weekly with a known volume of CO_2 discharged at a standard velocity from a calibrator instrument. The results of the tests were analyzed and printed by a Datamatic (Jones Medical Instrument Co.) computer that was connected to the spirometer.

Bronchial reactivity to histamine

Two days before the appointment, the parents were instructed to stop antihistamines and theophyllines and to administer no other bronchodilator medications for the 8 hours immediately before the visit, if it was possible. They were unable to stop medication in 23.1% subjects. A bronchial challenge test was not performed on these children nor on the children who reported a respiratory infection during the preceding 2 weeks, had an FEV_1 < 60% predicted or below 1L in volume, or were themselves smokers. The test was performed on the day on which they were first observed in all of the remaining 41 subjects.

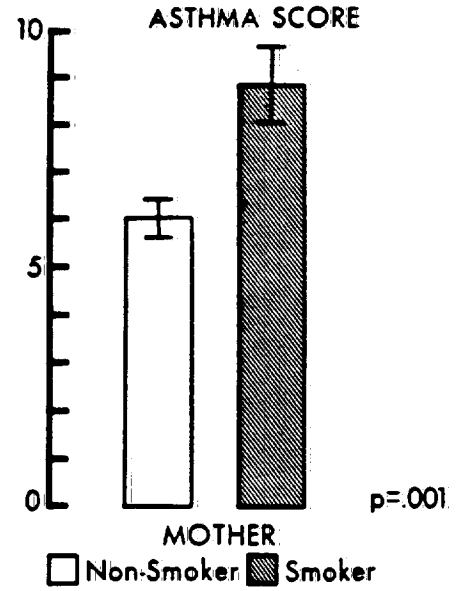

FIG. 1. The asthma history severity score, which ranges from a minimum of 0 to a maximum of 14, in two groups of children with a history of wheezing. The mothers of 69 were nonsmokers, and mothers of 23 were smokers. Means ± standard errors are presented.

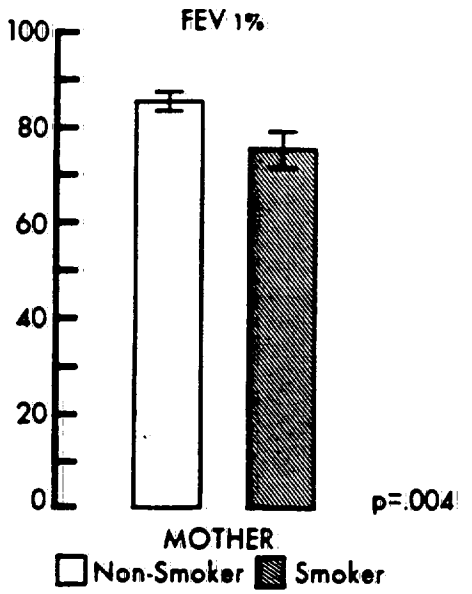

FIG. 2. The FEV_1 percent predicted in two groups of children with a history of wheezing. The mothers of 70 were nonsmokers, and mothers of 24 were smokers. Means ± standard errors are presented.

By use of a modification[12] of the method described by Cockcroft et al.,[13] each patient was administered doubling concentrations of histamine acid phosphate aerosol by mask, each inhalation session lasting for 2 minutes until PC_{20}. The strongest concentration administered was 8 mg/ml. Children whose FEV_1 did not decrease by 20% when this concentration was administered were deemed, for the purpose of calculating the mean PC_{20}, to respond to double that concentration, i.e., 16 mg/ml of histamine acid phosphate. There were two such subjects. The mothers were both nonsmokers.

Skin prick tests

By use of a standard method,[14] skin prick tests were performed on all subjects with negative and positive (histamine) control solutions, with 10% cigarette smoke (Bencard Division of Beecham Laboratories, U. K.), and with extracts of common inhalant and pollen allergens. The diameter of each resulting wheal was measured. If any wheal was 2 mm greater than that of the negative control solution, the test was regarded as positive and the patient as atopic. A 1% extract of *Dermatophagoides farinae* was included among those solutions tested, since the result would, if it were positive, be evidence not only of atopy but also of exposure to larger than usual numbers of house dust mites.[15]

The spirometric, bronchial challenge, and skin tests were performed by a technician who was unaware of the family's smoking habits.

Statistical method

Standard t tests were used to test differences between all quantitative variables except for those that were on a percentage scale, in which case a test of difference between normally distributed variates was applied. Pearson product-moment correlation coefficients were calculated as a measure of association.

RESULTS

The children were divided in the analysis into two groups on the basis of whether the mother did or did not smoke. These groups were comparable for age, gender, exposure to airborne irritants and allergens, percent that had had surgical operations, percent with frequent colds, proportion of subjects with atopy, and degree of sensitivity to house dust mites (Table I). The above mentioned variables were also comparable when the population was divided according to whether their fathers did or did not smoke.

Children of mothers who smoked had increased bronchial reactivity and worse asthma. Children whose mothers smoked had, on average, 47% more symptoms (Fig. 1), a 13% lower FEV_1 (Fig. 2), a 23% lower FEF_{25-75} (Fig. 3), and a fourfold greater responsiveness to aerosolized histamine (Fig. 4). All these differences between the two groups were highly significant (Table II). When the mean FVC percent

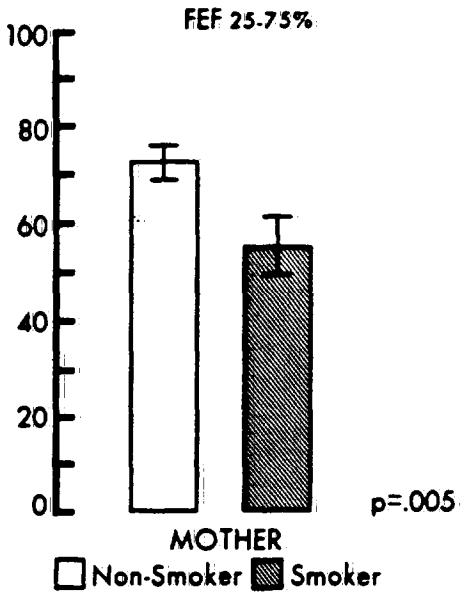

FIG. 3. The FEF_{25-75} percent predicted in two groups of children with a history of wheezing. The mothers of 70 were nonsmokers, and mothers of 24 were smokers. Means ± standard errors are presented.

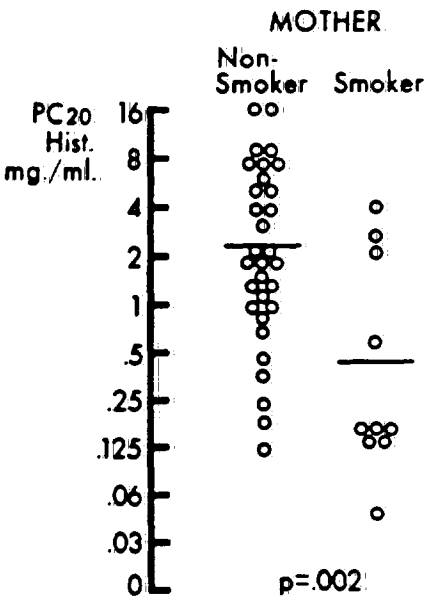

FIG. 4. The PC_{20} in two groups of children with a history of wheezing. The mothers of 32 were nonsmokers, and mothers of 10 were smokers.

predicted was examined, it was found not to be significantly different when the whole group of 94 subjects was considered. However, it was different in the subgroup of 41 subjects on whom the PC_{20} was performed, i.e., subjects whose values were not influenced by recent bronchodilator medications or by respiratory infections. In this subgroup, the FVC was 85.2 ± 2.7% in children of mothers who smoked and 97.5 ± 18% in children of mothers who did not smoke ($p = 0.002$). We were therefore able to demonstrate a significant difference between the two groups in all tests of asthma severity that were applied.

A dose response to the mothers' cigarette smoke is also apparent both in the whole group of 94 and in the subgroup of 41 subjects. There was a significant correlation between the logarithm of the number of cigarettes the mother smoked while she was in the home and FVC, FEV_1, FEF_{25-75}, asthma history score, and bronchial responsiveness to histamine (Table III). Not only was the correlation with bronchial responsiveness significant when all subjects with a baseline FEV_1 of 60% or more were included, but it remained significant ($p = 0.001$) when the analysis was restricted to subjects with a baseline FEV_1 of more than 70% predicted, the level usually accepted for histamine bronchial challenge testing.[15]

The effect of maternal cigarette smoke appears to be greater in older than in younger children, suggesting that not only the daily number of cigarettes but also the years of passive smoking increases the severity of its adverse effects. In children more than 11 years of age, there is, for example, a 19% difference in mean FEV_1 between the two groups, whereas in less than 11 years of age, the difference is only 9% (Table IV). Bronchial responsiveness in the older and younger subgroups could not be compared because it was assessed in only three of the older group whose mothers were smokers.

By contrast with the strong correlation between the mother's smoking habits and the severity of her child's asthma, there was no correlation between the number of cigarettes, cigars, or pipes of tobacco that the father smoked in the house and measures of lung function in the child (Table III), nor did the simple distinction of whether the father smoked or not smoked have any significant effect on any of the measurements (Table II). A partial explanation for the absence of effect may be the smaller number of cigarettes smoked at home by the father compared with the mother. Although the mean total of cigarettes that fathers smoked per day, 23, was slightly larger than that smoked by mothers, 18, the mean number that fathers smoked while they were in the house, eight, was significantly smaller than the number smoked in the house by mothers, 13.

Since there appeared to be no relationship between the smoking habits of the father and the severity of

TABLE II. Difference in indicators of asthma severity between groups distinguished by smoking habits of the parents

	History score*	FEV, percent predicted	FEF_{25-75}	Geometric mean PC_{20}†	
Mother					
Nonsmoker (n = 70)	6.0 ± 0.4	85.5 ± 1.8	72.3 ± 2.8	2.2	n = 31
Smoker (n = 24)	8.8 ± 0.8	74.4 ± 3.7	55.6 ± 5.6	0.46	n = 10
P Value (two-tailed)	0.001	0.004	0.005	0.002	
Father					
Nonsmoker (n = 64)	6.9 ± 0.5	81.9 ± 2.1	67.0 ± 3.1	1.7	n = 26
Smoker (n = 28)	6.4 ± 0.6	84.4 ± 2.9	70.5 ± 4.9	1.2	n = 15
p Value (two-tailed)	0.5	0.5	0.5	0.4	
Parents					
Both nonsmokers (n = 51)	6.2 ± 0.5	84.7 ± 2.1	71.6 ± 3.2	3.1	n = 21
Either smokes (n = 43)	7.4 ± 0.6	80.3 ± 2.7	63.8 ± 4.3	0.8	n = 20
p Value (two-tailed)	0.11	0.2	0.15	0.001	

Means ± standard errors are presented.
*History score available for 92 children.
†PC_{20} measured on all 41 children who were eligible for the test. T tests were carried out on logarithm of the PC_{20} values.

TABLE III. Correlation (r) between indicators of asthma severity and the logarithm of the number of cigarettes smoked in the house by the parents and the probability *(p)* of $r \neq 0$

	FVC (% Predicted)	FEV_1 (% Predicted)	FEF_{25-75} (% Predicted)	Log (PC_{20})	History score
Mother	r = 0.186	−0.300	−0.280	−0.482	0.224
	p = 0.039	0.002	0.004	0.001	0.018
Father	r = 0.036	0.028	0.001	0.075	0.084
	p = 0.367	0.395	0.495	0.319	0.218
Both parents	r = −0.081	−0.200	−0.227	−0.460	0.136
	p = 0.228	0.031	0.017	0.001	0.107

the child's asthma, the influence of both parents smoking, considered together, was less than that of only the mothers smoking (Table II).

The prevalence of smoking among the children was low. Only two of them admitted to being smokers. The mother of the one smoked, and the mother of the other did not. The skin prick test to cigarette smoke was negative in all subjects.

DISCUSSION

We found, in a series of unselected consecutively referred children with wheezing, that asthma was more severe if the mother was a smoker. The decreases in spirometric values that we observed were larger than any previously reported. In these other studies, the decrease in mean values, although the decrease was significant in some children, did not exceed 5% in any of the children.[1] Vedal et al.,[8] for example, detected a 3% reduction in mean FEF_{25-75} in children whose mothers smoked. We found a 23% reduction. Our results were also more consistent. With every test used we found a significant difference between those whose mothers did and did not smoke. Previous studies have found a significant difference with some tests but not with other tests. It is likely that the greater differences, which we observed, result from studying a group of children who have asthma rather than children who are representative of the population at large. An additional new finding in our study was that the child's bronchial responsiveness increased if the mother was a smoker.

The evidence suggests that it is airborne cigarette smoke that causes the adverse effect. Not only is there a strong association between maternal smoking and severity of the child's asthma, but there is also evidence of a dose response. We found a significant correlation between all indicators of asthma severity and the logarithm of the number of cigarettes the mother smoked while she was in the home. There was also evidence that length of exposure had an effect. The

TABLE IV. Differences in indicators of asthma severity between groups distinguished by age and by smoking habits of the mother

	History score*		FEV_1 % predicted		FEF_{25-75} predicted		Geometric mean PC_{20}†	
	Age (>11 yr)	Age (<11 yr)	Age (>11 yr)	Age (<11 yr)	Age (>11 yr)	Age (<11 yr)	Age (>11 yr)	Age (<11 yr)
Mother Nonsmoker	6.6 ± 0.5	5.3 ± 0.6	84.5 ± 2.8	86.7 ± 2.2	73.6 ± 4.1	70.8 ± 3.7	2.3 n = 20	2.1 n = 11
Mother Smoker	10.1 ± 0.9	7.8 ± 1.2	68.7 ± 6.4	79.2 ± 4.0	52.0 ± 10.5	58.6 ± 5.6	0.4 n = 3	0.5 n = 7
p Value (two-tailed)	0.005	0.07	0.04	0.12	0.07	0.08	0.06	0.02

Forty-eight subjects were aged 11 years or older, and 46 were younger than 11 years. Means ± standard errors are presented.
*The history score was available for 92 children.
†The PC_{20} was measured on 41 subjects.

older children, who had presumably been exposed to cigarette smoke for more years than the younger ones, were more severely affected. This finding is similar to that of Tager et al.[18] They reported that the normal rate of increase in FEV_1 during adolescent growth is slowed in children whose mothers smoked. Further evidence, that it is passively inhaled smoke that is responsible for the changes, is the effect observed when the mother stops smoking. Vedal et al.[8] report that children whose mothers are current smokers do but children whose mothers are exsmokers do not have significant differences in pulmonary function from those whose mothers are nonsmokers.

In contrast to the smoking habits of the mother, those of the father had no significant correlation with the severity of the child's asthma. These findings agree with those in more recently published large epidemiologic studies.[8, 9] Several factors may account for this apparent paradox. One is our finding that the father, compared with the mother, smokes significantly fewer cigarettes when he is at home. Another is the possibility that the mother, more frequently than the father, is in the same room as the child when she smokes a cigarette. A third possibility is that the number of cigarettes smoked in the house are more accurately reported for the mother than for the father. The mother was usually the person who gave the information. Whatever the reason, the father's smoke did not appear to influence the child's asthma significantly. When we examined the effect of maternal and paternal smoking together, therefore, we found it to be less clear than when we examined the result of maternal smoking alone. This observation may explain the lack of effect of parental smoking on wheezing and spirometric values reported in some epidemiologic studies.[2, 3, 6]

It appears unlikely that greater exposure to respiratory infections or allergens was responsible for the increased severity of asthma in children whose mothers smoked. Comparable proportions in both groups had frequent colds, had a cat or a dog in the house, and had a positive skin test to an inhalant allergen. Furthermore, the skin prick test reaction to *D. farinae* was smaller, if anything, in the group whose mothers were smokers, and it did not appear that the mothers who were nonsmokers more readily sought medical advice for their children than did those who were smokers. The frequency of surgical operations was similar in the two groups; however, this possibility could not be excluded.

Why cigarette smoke should increase asthmatic symptoms is not known. One possibility is that bronchial epithelium is damaged, irritant receptors are stimulated, and bronchial responsiveness is increased.[19] Another possibility is that a specific allergen in tobacco leaf or smoke may be responsible. Lehrer et al.[20] explored this possibility but found no association between clinical symptoms from smoke and positive skin prick tests, precipitating antibodies, or specific IgE to tobacco smoke. Similarly, in our study, all skin prick tests to smoke were negative, but these findings do not exclude the possibility that the adverse effect of cigarette smoke is immunologically mediated. Two observations suggest that it may be. One is the presence of abnormally high IgE reported in adults who smoke[21] and in the children of smokers[22] and the other is an increased bronchial responsiveness, both in healthy adults who are smokers[10, 11] and in our study population of children with asthma whose mothers were smokers. Increased responsiveness of the bronchi often results after the lung has been the site of an allergic reaction.[23] Burrows et al.[24] suggest ways, other than acting as a common inhalant allergen, in which tobacco smoke may elicit an allergic reaction in the lung.

Our findings indicate that maternal smoking aggra-

vates asthma in children, the effect being clinically important as well as statistically significant. Paternal smoking was not related to the severity of the child's asthma, but a possible explanation for this is that most of the father's cigarettes are smoked when he is away from home. Physicians who observe children with asthma should ask the parents if they smoke. Parents that do smoke should be advised to stop smoking, at least when they are in their house.

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APPENDIX

History	Asthma history score*				
	0	1	2	3	4
Severity, parents assessment	None	Mild	Moderate	Severe	—
Days of wheeze	None	1 to 3	4 to 182	182 to 365	—
Days of medication	None	1 to 3	4 to 30	31 to 182	183 to 365
Corticosteroid medication	None	—	—	Yes	—
Wheeze on exertion	None	Yes	—	—	—

*Numerical score indicating severity assigned to each feature in the history.